Voids Filling of DEM Generated by SRTM

Hussain Zaydan Ali   Halah Jaafar Mahdi Al- sammarraie
Ministry of Science and Technology, Directorate of space and communication
Baghdad-Iraq
E-mail: hussainzayali53@yahoo.com

Abstract

Information about the shape of the Earth's surface are required for several tasks like the creation of orthoimages or flood modeling. Digital elevation model (DEM) is generated by interferometric synthetic aperture radar (InSAR) and used in this paper. A digital elevation model (DEM) is one of the fundamental pieces of information needed to understand and manage the land. In its original release, SRTM data contains regions of no-data (voids), specifically over large water bodies, such as lakes and rivers, and in areas where radar-specific problems prevented the production of reliable elevation data. In many cases, these voids must be filled using void filling process. Therefore, a void-filling procedure has been applied to provide a continuous DEM. In this paper we applied the void filling algorithm for two cases. The results indicate that the statistical parameters are maintained for both cases, and they were in a good agreement with the original digital elevation model. The histograms obtained also shows identical results.

Keywords: Remote Sensing, DEM, SAR and Voids.

ملء فجوات موديل الارتفاع الرقمي المنتج بواسطة مهمة مكوك الفضاء الراداري الطبوغرافية

حسين زيدان علي   هالة جعفر مهدي السامرائي

وزارة العلوم والتكنولوجيا ، دائرة الفضاء والاتصالات

بغداد ـ العراق

الخلاصة

تعتبر المعلومات على شكل سطح الأرض ضرورية لعدة وظائف مثل إنتاج الصور المصححة الأبعاد الثلاثة أو نمذجة الفيضان. يتولد موديل الارتفاع الرقمي بواسطة رادار الفتحة المصطنعة التداخلية وقد تم استخدامه في هذا البحث. يعتبر موديل الارتفاع الرقمي من الأجزاء الأساسية من المعلومات التي نحتاجها لفهم وإدارة الأرض. إن مهمة المكوك الفضائي الراداري الطبوغرافية تحتوي بيانات   SRTM في نسخته الأولية مناطق لا تحتوي على بيانات (فجوات)، خصوصا فوق الأجسام المائية الكبيرة مثل البحيرات والأنهار وفي المناطق حيث المشاكل الخاصة بالرادار تمنع إنتاج بيانات ارتفاع موثوق. هذه الفجوات وفي عدة حالات يجب أن يتم ملئها باستخدام عملية ملء الفجوة. لذلك فان عملية ملء الفجوات تم تطبيقها لإنتاج موديل ارتفاع رقمي مستمر. في هذا البحث تم تطبيق خوارزمية ملء الفجوات لحالتين. أثبتت النتائج بان المعاملات الاحصائية تم الحفاظ عليها لكلا الحالتين، و كانت على توافق تام مع موديل الارتفاع الرقمي الاولي. كذلك فان المخططات التكرارية التي تم الحصول عليها بينت نتائج مماثلة.

الكلمات المفتاحيه: الاستشعار عن بعد ، موديل الارتفاع الرقمي ، رادار الفتحة المصطنعة والفجوات.

Introduction

Digital elevation models (DEM) from satellite data are generated mainly from two types of datasets using completely different methods: photogrammetry for optical stereo images (e.g. SPOT5) and interferometry for Synthetic Aperture Radar data (InSAR). During an 11 day flight in February 2000, the Space Shuttle Endeavor conducted the Shuttle Radar Topographic Mission (SRTM), a large-scale survey that collected interferometric radar topography data between 56°S and 60°N latitude. Interferometric SAR uses phase information from two SAR images of the same area. A complete DEM was generated with data from the Shuttle Radar Topography Mission (SRTM) in 2000(Brown and Sarabandi 2005; Sun, *et.al.*2003). The C-band DEM is of high quality due to its viewing geometry and high coherence, but only a ground sampling distance of about 90 m is available to the public. There are two resolutions of SRTM data, one is 1 arc second for US (SRTM1), and another one is 3 arc seconds for the rest of the world (SRTM3). Land cover is an important factor affecting the calculation of elevation when using Interferometer Synthetic Aperture Radar (InSAR). The importance of SRTM data for the environment study has been widely recognized (Rebus, *et.al.* 2003; Rodriguez, *et.al.* 2006).

Voids Reasons and Voids Filling Programs

Geospatial applications such as mapping, hydrology, geology, navigation, GIS, mission planning and simulation require the construction of a high resolution DEM of land surfaces of the Earth. SRTM provides an excellent representation of the real world with the resolution levels of ~30 and ~90 m at the Equator (Yue *et.al.* 2010). However, SRTM data has various sized holes, or voids, resulting in incomplete datasets. This causes many analysis processes (e.g. ortho-rectification, viewshed generation) to fail. Some of these voids can be attributed to the complex nature of InSAR technology(Grohman, *et.al.* 2006), while topographic shadowing can cause others. Simple interpolation does not fill these gaps adequately. Also in InSAR DEM, gaps occur due to radar shadow and layover, especially in steep terrains. In general, the quality of the derived DEM depends on the steepness of the terrain and on the land cover type. The majority of voids caused by phase unwrapping, shadowing and layover effects are located around water bodies (lakes and shorelines), in mountains and in desert areas. Many authors(Hall, *et.al.* 2005; Reuter, *et.al.* 2007) studied the voids of SRTM elevation data on the global landmasses. Global statistics provided by NASA JPL suggest that voids amount to 0.15% of the SRTM data in average but can be more extensive in specific areas. In mountainous areas, data voids can cover as much as 30% of the area. The finished SRTM data were referenced to the WGS84 ellipsoid for horizontal datum, i.e. geographical coordinates, and to mean sea level defined by EGM96 geoid for vertical datum. Small voids have been successfully filled by means of interpolation of values around the edges. Large voids cannot be simply interpolated from the edges and need to be filled with topographic information from other sources. Any areas of missing data that exist in the SRTM data are defined as voids. Void filling is the process of filling all no-data areas using the best-performing interpolation algorithm available (Chaplet, *et.al.* 2006). Many approaches have been developed to fill voids in SRTM digital

elevation data such as fill and feather (FF), inverse distance weighted interpolation (IDW)-based delta surface fill (DSF), triangulated irregular advanced Spline method. The FF method replaces a void with the most accurate digital elevation source available and then smoothes the transition to mitigate any abrupt change, in which the void-specific bias of the alternative surface is removed by adding a constant and then feathered at the edges to provide a seamless transition. FF corrupts the presumably correct SRTM surface at the void edges and cannot account for varying vertical biases within the void(Luedeling, *et.al*. 2007). The process of DSF replaces the void with fill source posts that are adjusted to the SRTM values found at the void interface, in which the IDW is used. TDS is a method similar to DSF, in which voids are filled by TINs that connect the points bordering the voids. All interpolation methods for void filling use the elevation data surrounding the void if auxiliary data are unavailable. If auxiliary sources of elevation are available,

then some of these algorithms can incorporate this information to improve the accuracy of the interpolation. The quality of different methods has been evaluated. The void filling errors of Spline, Kriging and linear estimations were comparatively analyzed in hilly, mountainous and planar areas, respectively; the results indicated that

network (TIN)-based delta surface (TDS), Kriging, Spline and the

there are no significant differences between the results obtained by using the three methods. They concluded that there was no single interpolation method that is the most accurate for the interpolation of terrain data after they reviewed the source and nature of errors in DEMs and in the derivatives of such models. Some methods can be easily available on the Internet.

Materials and Methods

The studied area (Figure 1) is located between the following two corners in degrees, minutes, seconds:

Upper left corner:
X = 40 07 41.5E
Y = 31 41 27.42N
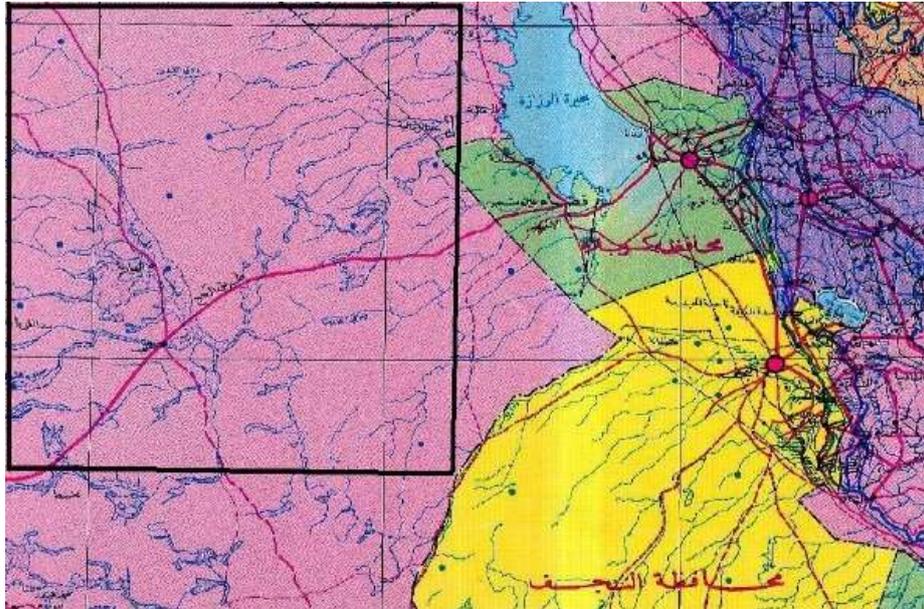
Lower right corner:
X = 44 30 31.63
Y = 31 22 8.37N

Figure (1) The Studied Area is Located Southwest in the Map

The studied area is well suited for the evaluation of the SRTM. The DEM data was transformed from geographic coordinate system into a UTM coordinate system. A cubic convolution method is used for the re-sampling process with the resulting grid size of 90×90 m. Then, the data were cut, the remaining data consist of a 400×400 grids corresponding to a region measuring 36 ×36 km. Figure (2) and (3) represent the, gray scale and color coded DEM produced from SRTM data.
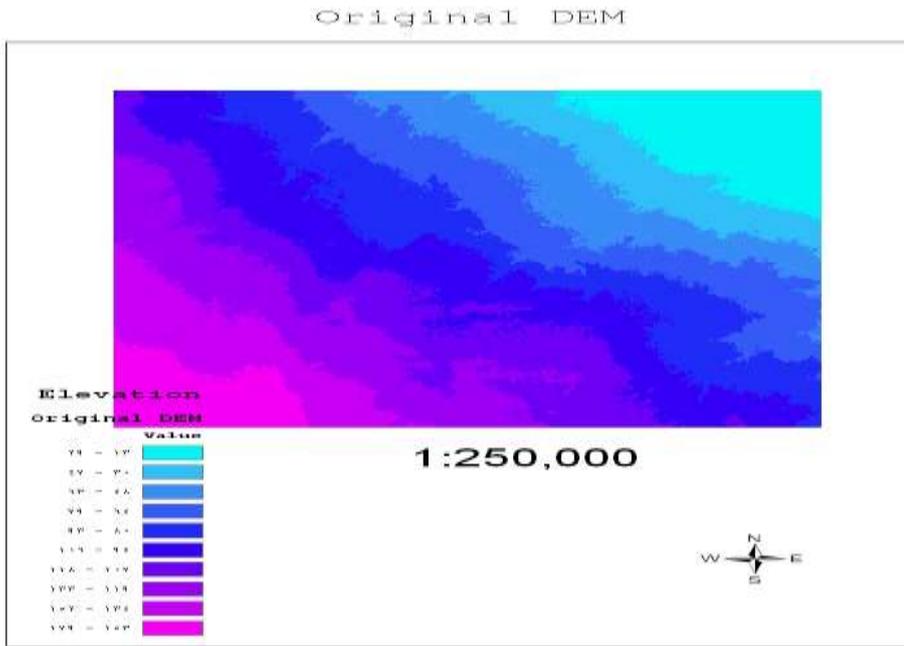

Figure (2) Original DEM

Original DEM

Figure (3) Original DEM Color Coded.

The slope and aspect of terrain were calculated according to the function in ArcGIS 9.3. Each point within the TIN in figure (4) having slope and aspect and elevation.
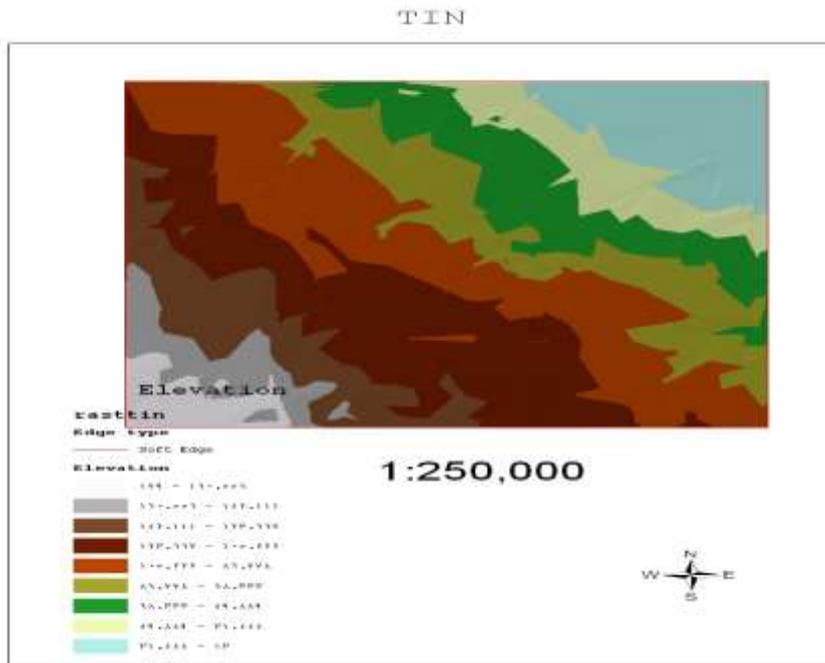
TIN

Figure (4) TIN of the Studied Area.

Altitudes within this studied area range from 13 m to 179 above sea level. A histogram of the elevation data is presented in Figure (5)
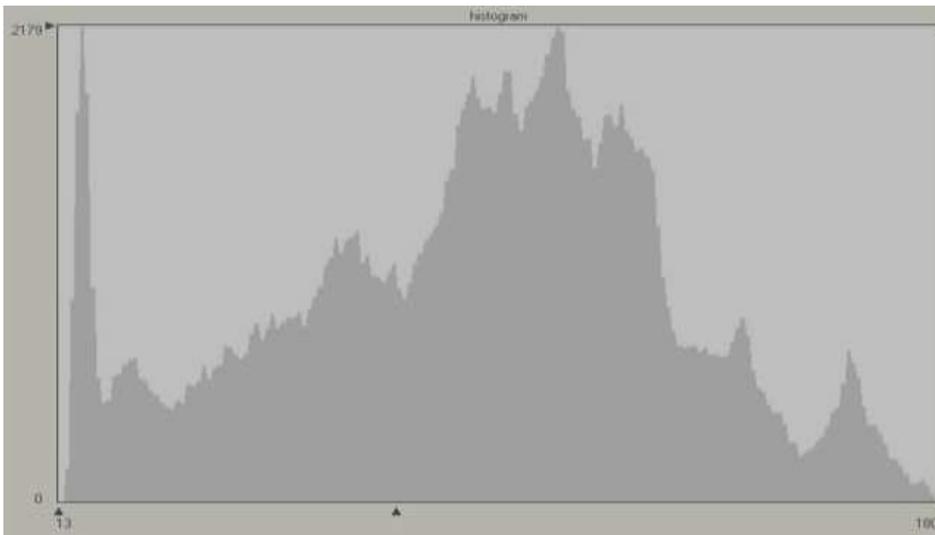
Figure (5) Histogram of DEM Shown in Figure (2).

Below are the statistical parameters of the above DEM

Table (1) Statistical Parameters

Min.	Max.	Mean	Median	Mode	Std. Dev.
13	179	91.214	96	107	37.538

The following programs were used in this paper: ERDAS Version 9.2, ArcGIS Version 9.3, and 3DEM to produce voids-less DEM. The paper aims to provide a void-less DEM and improve the overall accuracy.

Results and Discussion

The following two cases represent the Results of applying 3DEM program to on DEMs with voids. Voids are added using ERDAS IMAGINE Version 9.2.

Case (1):

Voids were added to the original DEM, as shown in figure (6). The statistical parameters of this DEM are shown in table (2).

Figure (6) DEM with Voids.

Table (2) Statistical Parameters.

Min.	Max.	Mean	Median	Mode	Std. Dev.
0	179	90.611	95	107	38.216

Using 3DEM program to remove the voids
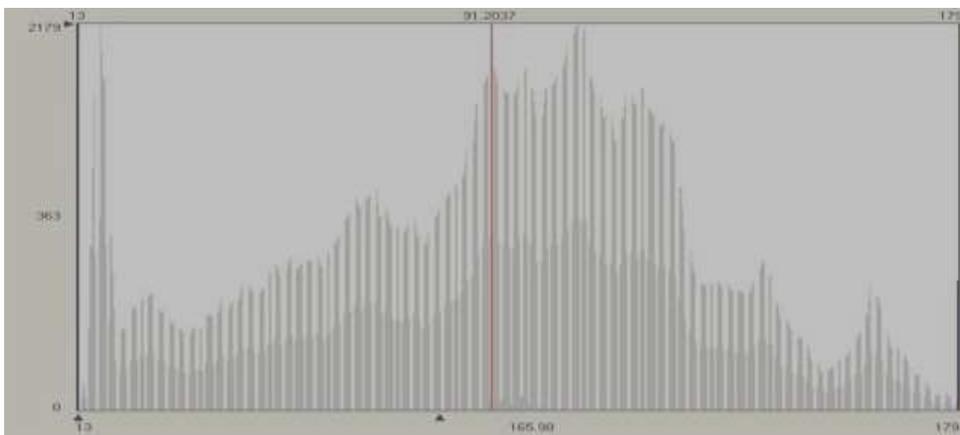 and the resulting DEM is shown in figure (7).

Figure (7) Void-less DEM.

The statistical parameters of this
 DEM are shown in table (3).

Table (3) Statistical Parameters.

Min.	Max.	Mean	Median	Mode	Std. Dev.
13	179	91.204	94.703	106.38	37.537

The histogram of the processed DEM is
shown below in figure (8).

Figure (8) Histogram of DEM Shown in Figure (7).

Case (2):

Voids were added to the original DEM, as shown in figure (9). The statistical parameters of this DEM are shown in table (4). We choose two regions from the original DEM.

Figure (9) DEM with Voids.

Table (4) Statistical Parameters.

Min.	Max.	Mean	Median	Mode	Std. Dev.
0	179	90.270	96	107	38.8

Figure (10) The Void-less DEM.

The statistical parameters of the DEM

in figure (10) are shown below (Table (5)).

Table (5) Statistical Parameters

Min.	Max.	Mean	Median	Mode	Std. Dev.
13	179	91.301	95.5	106.46	36.359

Conclusion

Information about the shape of the Earth's surface are required for several tasks like the creation of orthoimages or flood modeling. A lack of suitable topographic data has long been an obstacle to the study of the environment, especially for most developing countries. New remote sensing technologies have now begun to change this situation. Generally speaking, SRTM is a successful space-based topographic surveying practice. Due to the complex nature of SAR technology combined with the sensitive interaction of radar energy with the atmosphere and ground targets, the data contained a number of voids. Geospatial applications (GIS, cartography, geodesy, photogrammetry, remote sensing etc.) generally require a fully populated elevation dataset. If the elevation datasets contain voids, they have limited applications and are less useful. Therefore many end users and researchers have developed their own ways to fill voids that remain in the finished SRTM data set.

References

Brown, C. G. and Sarabandi, K., (2005). Validation of the Shuttle Radar Topography Mission Height Data, IEEE Transactions On Geoscience and Remote Sensing, 43(8), 1707–1715.

Chaplet, V., Darboux, F., Bourennane, H., Leguedois, S., Silvera, N. and Phachomphon, K., (2006). Accuracy of Interpolation Techniques for the Derivation of Digital Elevation Models in Relation to Landform Types and Data Density. Geomorphology, **77**,. 126–141.

Grohman, G., G. Kroenung, and J. Strebeck (2006). Filling SRTM Voids: The Delta Surface Fill Method, Photogrammetric Engineering and Remote Sensing 72(3), 213-216.

Hall, O., Falorni, G., and Bras, R. L., (2005). Characterization and Quantification of Data Voids in the Shuttle Radar Topography Mission Data. IEEE Geoscience And Remote Sensing Letters, 2(2), 177–181.

Luedeling, E., Siebert, S. and Buerkert, A., (2007). Filling the Voids in the SRTM Elevation Model – a TIN-Based Delta Surface Approach. ISPRS Journal of Photogrammetry and Remote Sensing, **62**, 283–294.

Rabus, B., Eineder, M., and Bamler, R., (20030. The Shuttle Radar Topography Mission—A New Class of Digital Elevation Models Acquired by Spaceborne Radar. ISPRS Journal Photogrammetry Remote Sensing, 57, 241–262.

Reuter, H.I., Nelson, A. and Jarvis, A., (2007). An Evaluation of Void-Filling Interpolation Methods for SRTM Data. International Journal of Geographical Information Science, **21**, 983–1008.

Rodriguez, E., Morris, C. S., Belz, J. E., (2006). A Global Assessment of the SRTM Performance. Photogrammetric Engineering and Remote Sensing, **72**,249–260.

Sun, G., Ranson, K.J., Khairuk, V.I. and Kovacs, K., (2003). Validation of Surface

Height from Shuttle Radar Topography Mission Using Shuttle Laser Altimeter. Remote Sensing of Environment, **88**,401–411.

Yue, T.X., Song, D.J., Du, Z.P. and Wang, W., (2010). High Accuracy Surface Modeling and Its Application to DEM Generation. International Journal of Remote Sensing, **31**, 2205–2226.